Resurvey of Northern Abalone, *Haliotis kamtschatkana*, Populations Along the Central Coast of British Columbia, April 2001

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RESURVEY OF NORTHERN ABALONE, *Haliotis kamtschatkana*, POPULATIONS ALONG THE CENTRAL COAST OF BRITISH COLUMBIA, APRIL 2001

by

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ABSTRACT

Lessard, J., Atkins, M. and Campbell, A. 2007. Resurvey of northern abalone, *Haliotis kamtschatkana*, populations along the central coast of British Columbia, April 2001. Can. Manuscr. Rep. Fish. Aquat. Sci. 2791: vi + 35 p.

As a result of over-exploitation, the legal harvest of northern abalone, *Haliotis kamtschatkana*, was closed in 1990. Since 1978, the Department of Fisheries and Oceans Canada has conducted periodic surveys of index sites along the coast of British Columbia (BC) to monitor the status of abalone populations. In 2001, the index sites along the central coast of BC were resurveyed. Two hundred and thirty abalone were measured at 40 (72.7%) of the 55 historic index sites surveyed. The overall density was 0.27 abalone/m^2; the lowest density observed in the nine surveys of this area since 1978. Densities of mature (≥70 mm shell length) abalone were also at their lowest levels. Abalone ≥100 mm shell length were observed at only 25% of sites surveyed. Statistical comparisons were made for size and density across years. There was no evidence of abalone population recovery along the central coast. Poaching continues to be the main concern preventing the recovery of abalone populations in British Columbia.

RÉSUMÉ

Lessard, J., Atkins, M. and Campbell, A. 2007. Resurvey of northern abalone, *Haliotis kamtschatkana*, populations along the central coast of British Columbia, April 2001. Can. Manuscr. Rep. Fish. Aquat. Sci. 2791: vi + 35 p.

La pêche de l'ormeau nordique, *Haliotis kamtschatkana*, de la Colombie-Britannique est complètement fermée depuis 1990 afin d'assurer la conservation de l'espèce. Des relevés à des sites indicateurs ont été effectués par Pêches et Océans Canada depuis 1978 pour surveiller le rétablissement des populations d'ormeaux. En avril 2001, 230 ormeaux ont été mesuré à 40 des 55 sites échantillonnés sur la côte central ouest de la Colombie Britannique. La densité totale estimée était de 0.27/m^2, une baisse significative comparée à tous les échantillonnages précédents. Les densités d'ormeaux mature (≥70 mm de longueur) étaient elles aussi à leurs plus bas niveaux comparativement à tous les échantillonnages précédents. Les ormeaux de ≥100 mm de longueur étaient présents à seulement 25% des sites échantillonnés. Les résultats indiquent que les populations d'ormeaux nordiques ne se rétablissent pas sur la côte central ouest de la Colombie Britannique depuis la fermeture de la pêche.

INTRODUCTION

Occurring in patchy distributions on exposed or semi-exposed coastlines in British Columbia (BC) the 'northern' or 'pinto' abalone, *Haliotis kamtschatkana*, is found from Yakutat, Alaska to Baja California (McLean 1966; O'Clair and O'Clair 1998). Abalone were harvested by First Nations as a traditional food source, and were a target of recreational divers and a commercial fishery in BC until 1990 (Campbell 2000). The biology and fishery of the northern abalone were reviewed by Sloan and Breen (1988) and Farlinger and Campbell (1992).

Northern abalone stocks have been assessed through surveys of index sites in the north central coast of BC (Pacific Fishery Management Area (PFMA) 5 and 6) and southeast Haida Gwaii (Queen Charlotte Islands) (PFMA 2 east) using a standard survey design since 1978 (Breen and Adkins 1979). Much of the commercial fishery for northern abalone was conducted in these areas during 1977-90 (Harbo 1997). Survey results at index sites showed that population densities declined by more than 75% during the 1978-90 period (Winther et al. 1995; Thomas and Campbell 1996). As a result of these substantial decreases, the Department of Fisheries & Oceans Canada banned the harvest of northern abalone in December of 1990 due to conservation concerns. Despite the harvest closure, their numbers remained low and in 1999 northern abalone was listed as '*threatened*' (a species likely to become endangered if the limiting factors are not reversed) by the Committee on the Status of Endangered Wildlife in Canada (Campbell 2000; Jamieson 2001).

As a result of the official listing, a National Recovery Strategy for the Northern Abalone was prepared by the DFO and the Abalone Recovery Team (Abalone Recovery Team 2002). The short-term measurable objective set out in the recovery strategy is: "[to] ensure that mean densities of adult (≥100 mm shell length) northern abalone do not decline below $0.1/m^2$ at surveyed index sites in Haida Gwaii and North and Central Coast, and that the percentage of surveyed index sites without adult (≥100 mm SL) northern abalone does not increase to greater than 60%". In order to monitor and evaluate recovery efforts, the surveys of index sites have continued.

This paper presents the results of a survey of northern abalone conducted along the central coast of British Columbia during April 2001, and compares abalone density estimates with those measured in previous index site surveys along the central coast (Fig. 1)

METHODS

SURVEY METHODS

Eight central coast abalone surveys have been completed since 1978 (Adkins and Stephanson 1979; Breen and Adkins 1980, 1981, 1982; Breen et al. 1982; Boutillier et al. 1984; Farlinger and Bates 1986; Farlinger et al. 1991; Thomas and Campbell 1996; Campbell et al. 1998). In the early years (1978-1983), the surveyed sites were chosen because of good abalone abundances which were deemed harvestable. In 1983, an effort was made to resurvey some of these sites which were subsequently, if conditions

permitted, sampled every time a survey was completed on the north and central coast. The repeatedly surveyed sites are referred as 'index sites'. 'All sites' refers to both index sites and additional sites (sites not repeated in subsequent surveys). In 1997, the central coast abalone survey was expanded and many additional sites were randomly selected (Campbell et al. 1998). Of these 1997 additional sites, only the sites repeated in 2001 were included in the analysis presented in this paper in order to keep the number of sites sampled similar across survey years.

The previously surveyed sites were found from chart records, written site descriptions, photographs and GPS positions. The sites were not evenly distributed along the coast, but were grouped into nine general survey areas to facilitate sampling: North Banks Island (Is), Oswald Bay, Pemberton Bay, Lotbinière Bay, North Aristazabal Is, South Aristazabal Is, Stryker Is, Simonds Group and Spider Is (Fig. 1).

For this survey, as in the past, sites were surveyed using the method described by Breen and Adkins (1979). Once each site was located, divers placed a $1m^2$ quadrat at the top of the abalone habitat zone and then sampled 16 quadrats within a 7m by 16m area (4 rows of 4 quadrats). For each quadrat, divers recorded the algae cover and dominant species and the number of urchins, then cleared the quadrat of all kelp, sea urchins, and sea stars to ensure all exposed abalone were easily detectable. Divers then recorded the depth and substrate type, and measured, with callipers, the shell length (SL in mm) of each exposed abalone. If no abalone were encountered in the first eight quadrats, the dive was aborted and the site count was scored as zero.

ANALYTICAL METHODS

Data from all the central coast abalone index site surveys were recently entered in a Microsoft Access database. Some errors were corrected when preparing the data for the database; therefore estimates presented in this paper (Appendices 4, 5, 6) may differ slightly from previously published estimates.

A Kolmorgorov-Smirnov two-sample test was used to test for differences in mean shell length between each of the nine general survey areas in 2001 in order to look at difference at a finer scale. A one-way ANOVA was used to compare mean shell length over all survey years; if differences were detected at the 0.05 confidence level, a post-hoc Bonferroni test was used for comparisons between years.

Densities were calculated for each site as the number of abalone/m^2 for several size categories: 'all sizes' (total); immature (<70 mm SL); mature (≥70 mm SL); pre-recruit (92-99 mm SL); new-recruit (100-106 mm SL) and 'legal' (≥100 mm SL). (In this paper, the term 'legal' is used to denote a certain size group for spatial and temporal comparisons only. Abalone ≥100 mm SL were of legal size when the abalone fishery was open in BC prior to and during 1990.) The smallest size at which 100% of abalone are mature was found to be approximately 70 mm SL (Campbell et al. 1992). Growth curves provided by Quayle (1971) and Breen (1986) were used to estimate pre-recruit and new-recruit sizes for northern abalone. Occasionally, the number of abalone measured did not match the number counted during the dive because some may not

have been accessible or the shells were broken. Densities for each size category (d_i) were calculated as:

$$d_i = \frac{n_i}{n} \times d \qquad (1)$$

where n_i is the number of abalone measured in size category i, n is the total number of abalone measured in the sample and d is the density (abalone/m^2) calculated from the total abalone count from the 16 quadrats.

Many previous survey designs (1979, '80, '83, '85, '89, and '93) had divers turn boulders and rocks over in search of hidden or cryptic abalone, but in an effort to conserve time and increase sample size only exposed abalone were recorded in 2001. A lot of time is spent searching for cryptic individuals and the majority (>90%) of fully mature abalone (≥70mm SL) are exposed (Cripps and Campbell 1998). Data for cryptic abalone from years where counts were kept separate (1989 and 1993) were excluded from the analyses in this paper. For the years in which cryptic abalone were counted but the counts were not separated from the exposed counts (1979, '80, '83, and '85), a correction factor was used to account for the number of cryptic abalone from each site based on the frequency of cryptic abalone in 1989 and 1993. The factor was calculated as:

$$\text{correction factor} = 1 - \frac{c_{i89} + c_{i93}}{n_{89} + n_{93}} \qquad (2)$$

where c_i is the number of cryptic abalone in size category i in 1989 or 1993 and n is the total number of abalone (cryptic + exposed) in 1989 or 1993. The cryptic correction factors were 0.836 for immature (<70 mm SL) and 0.991 for mature (≥70 mm SL) as well as legal abalone (≥100 mm SL). No correction factors were calculated for the pre-recruit and new-recruit size categories as there were no cryptic animals in those size categories in 1989 or 1993. In addition, the correction factors would have little influence as the densities were very low for those two size categories and the factor for mature was almost equal to 1 with a much broader size range. Exposed densities for 'all sizes', for survey years in which cryptic and exposed abalone counts were not separated (1979, '80, '83, and '85), were calculated as the sum of immature and mature densities.

Previous analyses of index site surveys compared changes in densities between years for repeated sites only and several sites were ignored. This meant that each time a particular site was not surveyed because of weather conditions, or other reasons, the number of sites included in the analysis decreased. In Campbell et al. (1998) describing the 1997 survey results and comparing them with previous survey years, only 11 sites had the complete time-series. Considering the amount of effort necessary to survey each site, all sites should be included in the analysis, if possible. For this reason, the analysis in this paper was changed. The non-parametric Kruskal-Wallis test was used in order to include as many sites as possible while considering each site an independent sample. This made the comparison between years with different sample sizes possible. The Kruskal-Wallis test was used to compare densities between all years for all size categories; if differences were detected at the 0.05 confidence level, a Mann-Whitney U was used for comparisons between years.

RESULTS

SURVEY SUMMARY

A total of 55 index sites were sampled for abalone densities during eight dive days in April 2001. An average of 32.8 minutes (minimum 14, maximum 64) was spent sampling each site (Appendix 1). Generally the sites were composed of bedrock and/or boulder/cobble substrate, and many sites also had sand or shell. The dominant kelp species were: *Nereocystis luetkeana*, *Macrocystis integrifolia*, and *Laminaria* spp.; encrusting coralline algae were present at all sites (Appendix 2).

SIZE FREQUENCY

In 2001, 230 abalone were measured during the survey. The mean shell length was 77.6mm; the smallest abalone measured was 29mm and the largest was 122mm (Fig. 2; Table 1). The mean shell lengths at South Aristazabal Is and North Aristazabal Is were significantly smaller than North Banks Is and Simonds Group (Table 1). The mean shell length at South Aristazabal Is was also significantly smaller than Lotbinière Bay.

The mean shell length differed significantly between survey years. The mean SL was significantly larger in 1978 (94.9 mm SL) than all other years. The 1980 survey had the smallest mean size (74.2 mm SL), which was significantly smaller than all survey years, except 2001 (Table 2, 3).

DENSITY

In 2001, the mean 'all sizes' densities ranged from 0.08 abalone/m^2 (Oswald Bay) to 0.44 abalone/m^2 (North Banks Is) (Table 4). Density estimates by size category and by general survey area were very low or zero. There were no significant differences in the mean 'all sizes' density estimates between areas. North Banks Is had the highest density of 'all sizes', legal, and mature abalone.

Densities of abalone were compared across years by the different size categories (Table 5, 6; Fig. 4; Appendix 4, 5, 6). Abalone densities have been declining since 1980 (Fig. 4). The densities of 'all sizes' and mature abalone were significantly lower in 2001 than all previous years. Except for immature and pre-recruits, 2001 abalone densities were significantly lower than in 1989, shortly before the fishery closed, but all category densities were lower in 2001 than in 1985 and earlier.

PERCENT OF SITES WITH ABALONE

Abalone were found in all general survey areas during 2001 (Table 7). Overall, the percentage of sites with no exposed abalone was 27.3% (15 of the 55 sites sampled). Two out of the nine areas surveyed had no legal abalone: Pemberton Bay and South Aristazabal Is. The percentage of sites with no legal sized abalone rose from a low of 11.1% in 1985 to 72.7% in 2001 (Fig. 5).

DISCUSSION

The estimated abalone population density (mean 0.27 ± SE 0.04 abalone/m^2) along the central coast of BC in 2001 was lower than the most recent density estimate in the Queen Charlotte Islands in 2002 (0.34 ± 0.06 abalone/m^2) (Atkins et al. 2004), but was higher than the density estimated from the surveys completed along the northwest side of Vancouver Island in 2003 (0.09 ± 0.04 abalone/m^2) (Atkins and Lessard, 2004) and in Queen Charlotte and Johnstone Straits in 2004 (0.04 ± 0.01 abalone/m^2) (Davies et al. 2006). The results of the 2001 survey on the central coast were similar in many ways to the 2002 survey results from the southeast Queen Charlotte Islands (Atkins et al. 2004). Density estimates from all size categories showed significant decreases in both surveys. The decreases were proportionally larger for mature and legal abalone densities than for immature abalone densities. In 2001 central coast survey, the densities of mature and legal abalone declined by 43% and 60% respectively, while the density of immature abalone declined by 17%.

The reduction in densities of large abalone may be due to mortality caused by poaching and/or natural factors that include disease, parasites, predation, and crushing from storm events. Except for predation by sea otters, which were only present in a small portion of the surveyed areas (Nichol et al. 2005), most of the natural mortality causes would affect smaller abalone more than larger sized ones, or at least equally (see Bower (2000) for possible diseases and parasites, and Shepherd and Breen (1992) for predators).

Since the fishery closure in 1990, there probably has been a significant illegal harvest of northern abalone, evidenced by several abalone seizures in BC (Jubinville 2000; see Table 1 in Campbell 2000). From 1996 to Feb 2001, >15,000 abalone were seized (compiled through DFO press releases). However, fishery officers estimate that only 10-20% of poaching activity is prosecuted (B. Hume, DFO-C&P, Special Investigation Unit, Campbell River; pers. comm.). The mean size of all abalone poached, for which we have measurements, was 115.1 mm SL (±0.41SE) with a range of 70-154 mm SL and only 179 abalone out of 1239 were below the former legal size (≥ 100 mmSL). Therefore, despite the fact that size limit regulations do not apply anymore, poachers still preferentially select larger abalone. Campbell (1997) estimated the instantaneous fishing mortality to be 0.14 - 0.70 in some areas in central coast during the post-fishery closure (1993-96) period.

The three most southern general survey areas, Stryker Is, Simonds Group and Spider Is, were within, or in proximity of, the sea otter range (Nichol et al. 2005). Sea otters have been present in and around Stryker Is since 1996. They now have an established rafting site just south of Stryker Is (L. Nichol and J. Lessard, personal observations). To this day, sea otters have not established rafts in and around the Simonds Group and Spider Is, although they have been sighted in the Simonds Group (J. Lessard, personal observation). Although all three areas showed a decrease in abalone densities from the previous survey in 1997 (Campbell et al. 1998), the abalone densities in 2001 were higher or close to the overall mean (Table 4).

Since the closure of the abalone fishery in late 1990 there has been no evidence of abalone populations rebuilding along the coast of BC. Abalone density estimates during

this most recent survey along the central coast were the lowest ever observed of the nine central coast abalone surveys completed since 1978. In 2001, the overall density of legal abalone was 0.04/m^2 and 73% of all sites surveyed had no legal abalone. Both these measures indicated that the short term objectives of the abalone recovery strategy (respectively 0.1 legal-size abalone/m^2 and 60% of sites without legal-size abalone) were not met (Abalone Recovery Team 2002). Furthermore, the percentage of index sites without abalone of any size had also increased to 27% in 2001 (Fig. 5) which suggested that there were fewer patches of abalone than observed in previous surveys. Despite recovery efforts, abalone densities have continued to decline and poaching has probably persisted to be an important mortality factor.

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Table 1. Summary of exposed abalone shell length data from surveyed sites grouped in nine general areas on the central coast of BC, April 2001. SE = standard error of the mean. Means followed by the same letter were significantly different ($P< 0.05$) from each other, using a Kolmogorov-Smirnov test.

	Shell Length (mm)					Total	Percent Legal
Area	Mean	Median	SE	Minimum	Maximum	Count	(>100mm SL)
North Banks Is	86.0[a,b]	85.0	3.5	56	118	28	28.6
Oswald Bay	72.0	65.5	9.9	56	101	4	25.0
Pemberton Bay	76.5	80.0	4.4	48	99	14	0.0
Lotbinière Bay	82.2[c]	86.0	2.6	40	122	53	20.8
North Aristazabal Is	70.1[b,d]	68.0	3.5	38	112	34	2.9
South Aristazabal Is	58.3[a,c,e]	51.0	5.2	29	89	15	0.0
Stryker Is	75.3	76.0	4.1	30	115	27	11.1
Simonds Group	83.8[d,e]	87.5	3.4	32	118	34	26.5
Spider Is	75.4	80.0	4.7	34	122	21	9.5
All areas	77.6	81.0	1.4	29	122	230	15.2

Table 2. Mean abalone shell length (SL) in mm, standard error of the mean (SE) and number (N) of exposed abalone measured for 'all sites' sampled along the central coast by year.

	Year								
	1978	1979	1980	1983	1985	1989	1993	1997	2001
Mean SL	94.9	81.6	68.2	80.9	82.4	81.3	78.4	80.7	77.6
SE	1.0	0.7	0.7	0.6	0.8	1.4	1.1	1.4	1.4
N	454	804	959	1076	688	227	421	317	230

Table 3. ANOVA results comparing the mean shell length of abalone, from 'all sites', between years. Numbers represent P-values from the multiple comparison Bonferroni test. Bold numbers indicate significant difference (P= 0.05).

	Year							
Year	1978	1979	1980	1983	1985	1989	1993	1997
1979	**0.000**							
1980	**0.000**	**0.000**						
1983	**0.000**	1.000	**0.000**					
1985	**0.000**	1.000	**0.000**	1.000				
1989	**0.000**	1.000	**0.000**	1.000	1.000			
1993	**0.000**	0.396	**0.000**	1.000	0.073	1.000		
1997	**0.000**	1.000	**0.000**	1.000	1.000	1.000	1.000	
2001	**0.000**	0.395	**0.000**	1.000	0.098	1.000	1.000	1.000

Table 4. Mean exposed abalone density estimates (number/m^2) by size category and general survey area, central coast 2001.

	North Banks Is	Oswald Bay	Pemberton Bay	Lotbinière Bay	North Aristazabal Is	South Aristazabal Is	Stryker Is	Simonds Group	Spider Is	All Sites
No. of Sites	4	3	4	8	7	11	8	6	4	55
All sizes	0.44	0.08	0.22	0.41	0.31	0.09	0.23	0.35	0.36	0.27
	(0.13)	(0.06)	(0.10)	(0.14)	(0.12)	(0.02)	(0.13)	(0.23)	(0.17)	(0.04)
Immature	0.13	0.06	0.06	0.11	0.16	0.06	0.10	0.08	0.16	0.10
(<70 mm SL)	(0.04)	(0.06)	(0.04)	(0.07)	(0.05)	(0.01)	(0.06)	(0.05)	(0.10)	(0.02)
Mature	0.31	0.02	0.16	0.30	0.15	0.03	0.13	0.27	0.20	0.17
(≥70 mm SL)	(0.09)	(0.02)	(0.07)	(0.10)	(0.07)	(0.01)	(0.10)	(0.19)	(0.09)	(0.03)
Pre-Recruit	0.05	0.00	0.06	0.03	0.05	0.00	0.02	0.06	0.03	0.03
(92-99 mm SL)	(0.03)		(0.03)	(0.01)	(0.03)		(0.02)	(0.04)	(0.03)	(0.01)
New Recruit	0.05	0.02	0.00	0.05	0.00	0.00	0.01	0.07	0.00	0.02
(100-106 mm)	(0.02)	(0.02)		(0.02)			(0.01)	(0.06)		(0.01)
Legal	0.13	0.02	0.00	0.09	0.01	0.00	0.02	0.09	0.03	0.04
(≥100 mm SL)	(0.04)	(0.02)		(0.03)	(0.01)		(0.02)	(0.08)	(0.03)	(0.01)

Table 5. Mean exposed abalone density estimates (number/m^2) by year and size category, from 'all sites' surveyed on the central coast. The values in brackets are the standard errors of the mean.

	Year								
	1978	1979	1980	1983	1985	1989	1993	1997	2001
Number of sites sampled	12	14	19	42	28	26	33	47	55
All Sizes	2.40 (0.43)	2.94 (0.66)	3.09 (0.49)	1.58 (0.26)	1.50 (0.18)	0.55 (0.11)	0.46 (0.07)	0.42 (0.07)	0.27 (0.04)
Immature (<70 mm SL)	0.27 (0.09)	0.59 (0.13)	1.40 (0.31)	0.37 (0.08)	0.32 (0.07)	0.14 (0.05)	0.15 (0.02)	0.12 (0.03)	0.10 (0.02)
Mature (≥70 mm SL)	2.13 (0.38)	2.35 (0.61)	1.68 (0.30)	1.22 (0.21)	1.18 (0.17)	0.41 (0.08)	0.31 (0.06)	0.30 (0.06)	0.17 (0.03)
Pre-Recruit (92-99 mm SL)	0.32 (0.08)	0.48 (0.16)	0.24 (0.08)	0.24 (0.05)	0.25 (0.05)	0.07 (0.02)	0.06 (0.01)	0.06 (0.01)	0.03 (0.01)
New-Recruit (100-106 mm)	0.30 (0.06)	0.35 (0.12)	0.16 (0.04)	0.13 (0.03)	0.18 (0.04)	0.04 (0.01)	0.04 (0.01)	0.04 (0.01)	0.02 (0.01)
Legal (≥100 mm SL)	1.10 (0.22)	0.63 (0.17)	0.27 (0.09)	0.24 (0.04)	0.33 (0.07)	0.10 (0.02)	0.08 (0.02)	0.10 (0.02)	0.04 (0.01)

Table 6. Mann-Whitney U test probabilities comparing mean densities between years, by size category from 'all sites' on the central coast. P-values in bold indicate significant difference (P= 0.05).

	Year							
Year	1978	1979	1980	1983	1985	1989	1993	1997
All sizes								
1979	0.719							
1980	0.543	0.636						
1983	**0.030**	**0.026**	**0.003**					
1985	0.082	**0.035**	**0.008**	0.457				
1989	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**			
1993	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.957		
1997	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.337	0.238	
2001	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.006**	**0.002**	**0.023**
Immature Size (<70 mm SL)								
1979	0.072							
1980	**0.002**	0.109						
1983	0.958	**0.031**	**0.000**					
1985	0.848	0.053	**0.001**	0.728				
1989	0.075	**0.000**	**0.000**	**0.005**	**0.002**			
1993	0.397	**0.001**	**0.000**	0.105	0.070	0.080		
1997	**0.036**	**0.000**	**0.000**	**0.001**	**0.000**	0.931	**0.038**	
2001	**0.033**	**0.000**	**0.000**	**0.000**	**0.000**	0.835	**0.029**	0.882
Mature Size (≥70 mm SL)								
1979	0.719							
1980	0.240	0.362						
1983	**0.009**	**0.018**	0.075					
1985	**0.018**	**0.027**	0.182	0.577				
1989	**0.000**	**0.000**	**0.000**	**0.002**	**0.000**			
1993	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.380		
1997	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.113	0.259	
2001	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.002**	**0.031**
Pre-recruit size (92-99 mm SL)								
1979	0.719							
1980	0.244	0.107						
1983	0.193	0.073	0.950					
1985	0.425	0.286	0.373	0.315				
1989	**0.003**	**0.000**	**0.039**	**0.013**	**0.000**			
1993	**0.002**	**0.000**	0.070	**0.018**	**0.000**	0.485		
1997	**0.000**	**0.000**	**0.008**	**0.001**	**0.000**	0.729	0.200	
2001	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.157	**0.009**	0.205
New Recruit Size (100-106 mm SL)								
1979	0.520							
1980	0.067	0.166						
1983	**0.008**	**0.048**	0.403					
1985	0.063	0.165	0.744	0.464				
1989	**0.000**	**0.000**	**0.001**	**0.021**	**0.003**			
1993	**0.000**	**0.000**	**0.001**	**0.005**	**0.000**	0.535		
1997	**0.000**	**0.000**	**0.000**	**0.001**	**0.000**	0.186	0.328	
2001	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.003**	**0.015**	0.180
Legal Size (≥100mm SL)								
1979	**0.031**							
1980	**0.000**	**0.014**						
1983	**0.000**	**0.008**	0.742					
1985	**0.000**	0.051	0.415	0.493				
1989	**0.000**	**0.000**	0.149	**0.034**	**0.014**			
1993	**0.000**	**0.000**	**0.028**	**0.004**	**0.000**	0.452		
1997	**0.000**	**0.000**	**0.011**	**0.001**	**0.000**	0.182	0.362	
2001	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.002**	0.052

Table 7. Percent of index sites by general survey area where there were no exposed abalone, or no legal (≥100 mm SL) exposed abalone, during the 2001 central coast survey.

Area	% of zero sites		Number of sites
	Total	Legal	
North Banks Is	00.0	00.0	4
Oswald Bay	33.3	66.7	3
Pemberton Bay	25.0	100.0	4
Lotbinière Bay	25.0	37.5	8
North Aristazabal Is	14.3	85.7	7
South Aristazabal Is	18.2	100.0	11
Stryker Is	62.5	87.5	8
Simonds Group	33.3	66.7	6
Spider Is	25.0	75.0	4
Total	27.3	72.7	55

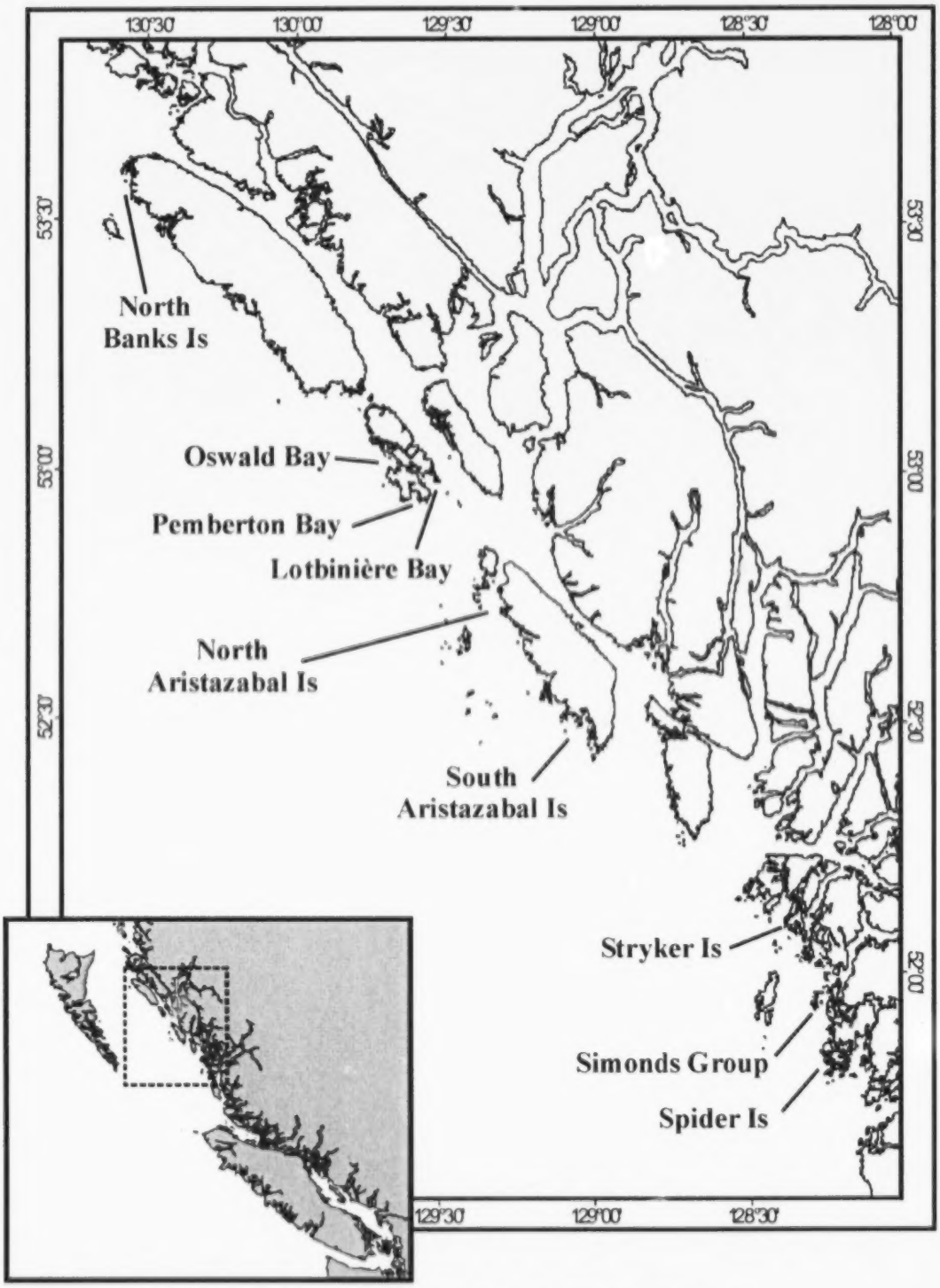

Figure 1. Map of general survey areas along the central coast of BC.

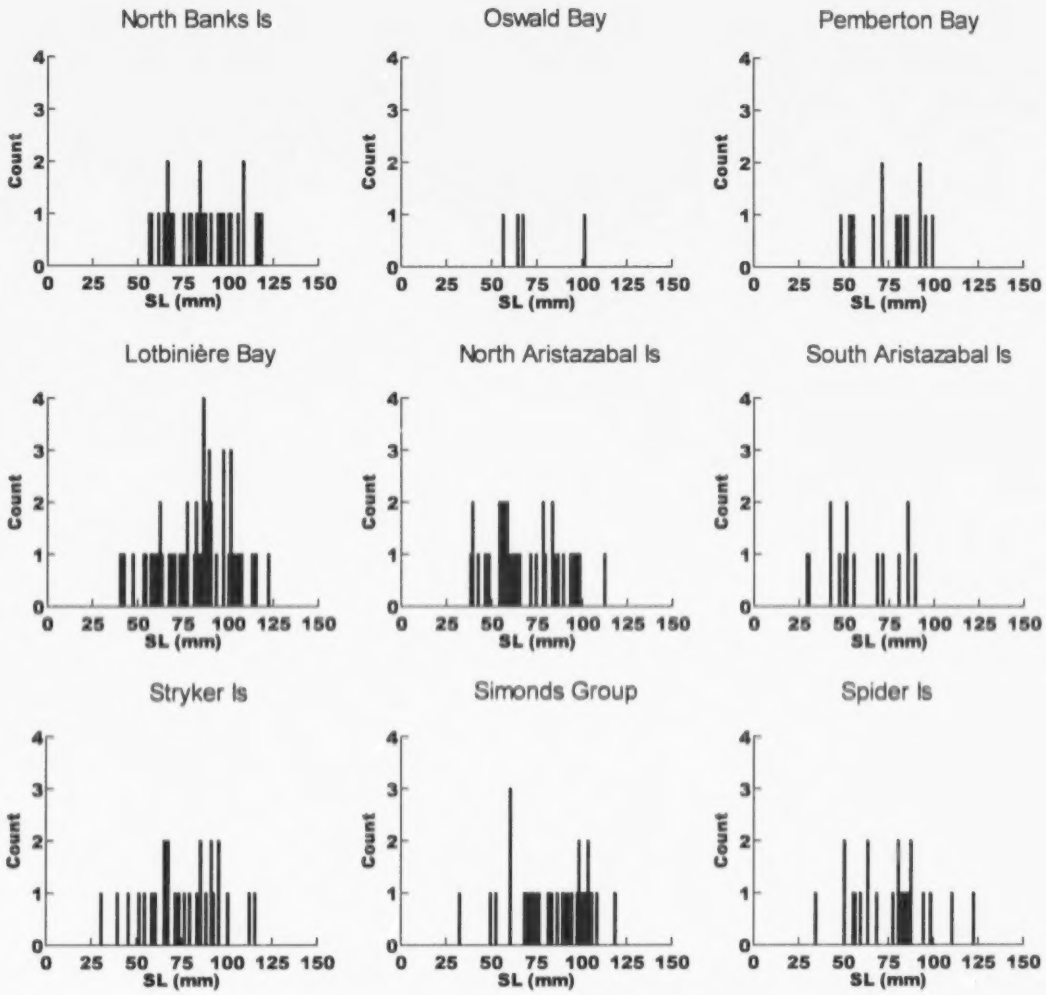

Figure 2. Size frequency of exposed abalone from each general survey area along the central coast, April 2001.

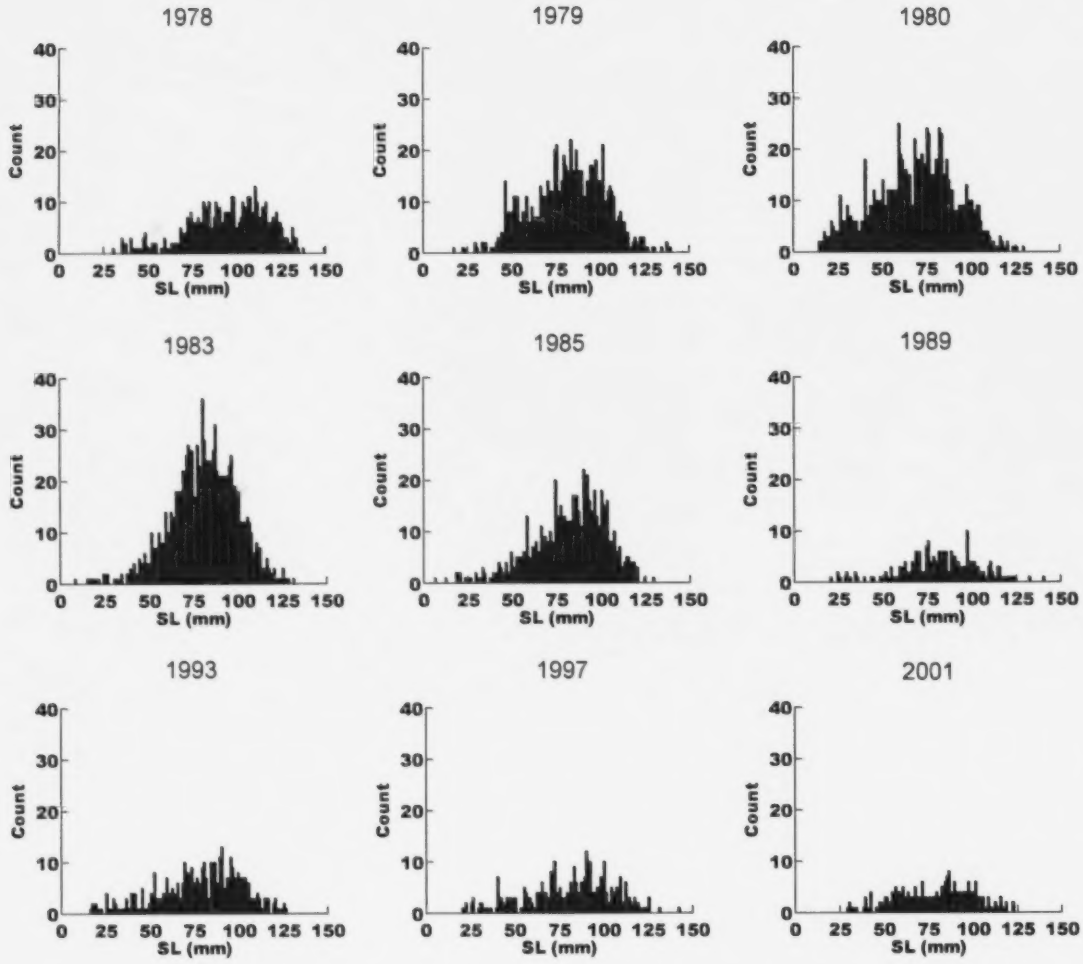

Figure 3. Size frequency of exposed abalone shell lengths (mm) measured from all sites for all survey years.

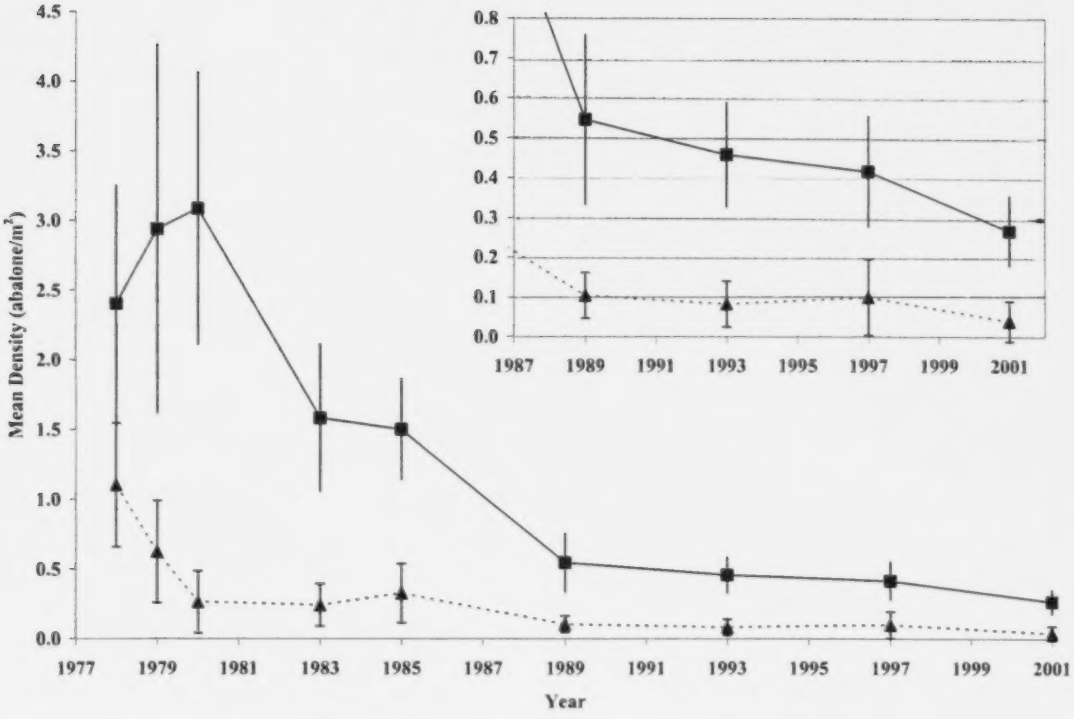

Figure 4. Mean density of 'all sizes' abalone (solid line) and legal abalone (dashed line) from all survey years. All sites surveyed are included. Error bars represent two standard errors. Inset graph displays greater resolution of densities for survey years after 1987.

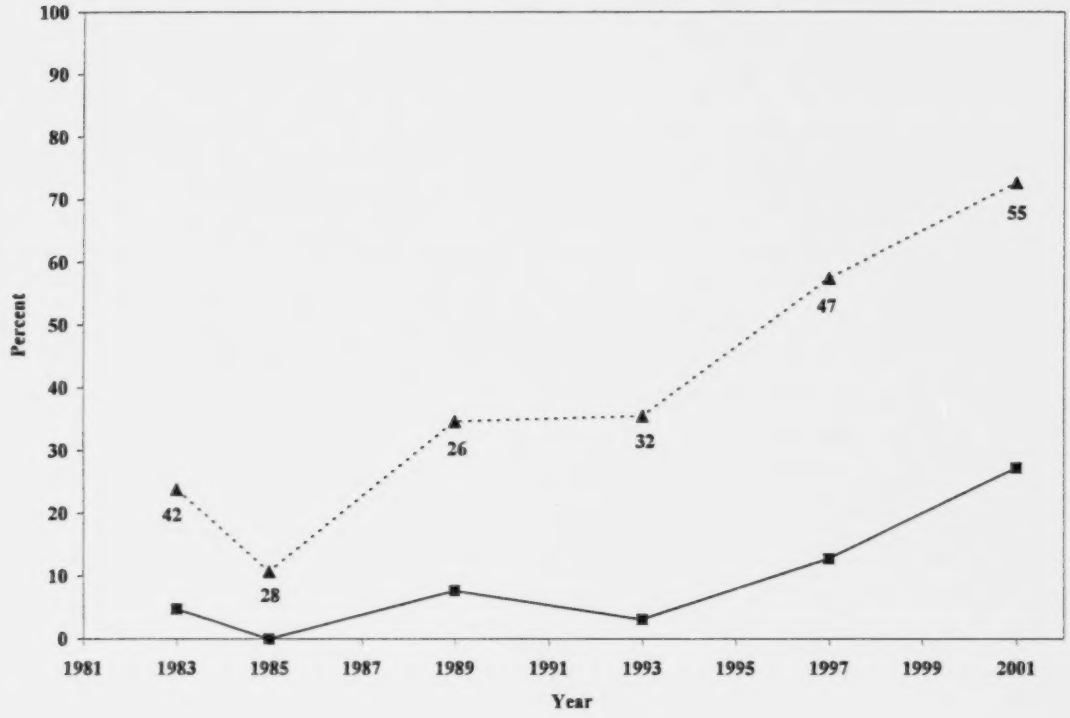

Figure 5. Percent of 'index sites' with no abalone of any size (solid line) or no legal abalone (≥100 mm SL) (dashed line) from surveys along the central coast, 1983-2001 (excluding 1978, 1979 and 1980 due to small number of 'index sites' in those years). Numbers are sample sizes.

Appendix 1. Dive survey summary of the 55 index sites sampled along the central coast of BC, April 2001.

Site	Date	Dive Time			Depth (m)		Number of quadrats	Total number of abalone	Density (abalone/m^2)
		Start	Finish	Minutes	Min	Max			
North Banks Is									
44	Apr-14	11:42	12:17	35	1	1	16	7	0.44
45	Apr-14	9:21	10:08	47	-1	1	16	1	0.06
46	Apr-14	9:04	9:35	31	0	1	16	10	0.63
47	Apr-14	10:34	11:03	29	1	2	16	10	0.63
Oswald Bay									
38	Apr-15	11:58	12:14	16	0	4	8	0	0.00
39	Apr-15	11:05	11:37	32	-1	2	16	3	0.19
40	Apr-15	9:48	10:24	36	0	0	16	1	0.06
Pemberton Bay									
33	Apr-15	11:11	11:40	29	0	1	16	0	0.00
34	Apr-15	14:22	15:05	43	-2	1	16	2	0.13
35	Apr-15	9:39	10:27	48	-2	1	16	5	0.31
36	Apr-15	13:00	13:42	42	0	2	16	7	0.44
Lotbinière Bay									
21	Apr-16	10:58	11:35	37	-1	1	16	6	0.38
22	Apr-16	9:53	10:30	37	1	2	16	7	0.44
23	Apr-15	16:03	16:34	31	1	2	16	11	0.69
24	Apr-16	9:57	10:16	19	-1	0	8	0	0.00
25	Apr-16	12:10	12:32	22	-1	3	16	1	0.06
27	Apr-16	8:52	9:34	42	0	0	16	0	0.00
29	Apr-16	12:26	12:53	27	0	2	16	18	1.13
30	Apr-15	14:21	15:05	44	1	2	16	10	0.63
North Aristazabal Is									
13	Apr-18	8:21	8:47	26	0	2	16	2	0.13
15	Apr-18	10:39	11:06	27	0	2	16	5	0.31
15A	Apr-18	11:22	12:00	38	-1	0	16	4	0.25
16	Apr-18	9:08	9:40	32	0	1	16	15	0.94
17	Apr-18	11:04	11:59	55	0	2	16	7	0.44
19	Apr-18	9:03	9:28	25	-1	0	16	0	0.00
20	Apr-18	9:53	10:11	18	0	2	16	1	0.06
South Aristazabal Is									
2	Apr-21	15:58	16:36	38	-2	3	16	1	0.06
3	Apr-21	14:03	14:33	30	-1	1	16	1	0.06
4	Apr-21	14:48	15:09	21	0	2	16	1	0.06
5	Apr-21	15:41	16:01	20	-1	2	8	0	0.00
6	Apr-21	13:39	14:12	33	-2	2	16	2	0.13
7	Apr-21	16:19	16:49	30	3	5	16	2	0.13
8	Apr-21	10:38	11:09	31	0	4	16	1	0.06
9	Apr-21	13:02	13:39	37	0	0	16	3	0.19
10	Apr-21	9:12	9:36	24	0	2	8	0	0.00
11	Apr-21	8:49	9:18	29	-1	2	16	2	0.13
12	Apr-21	10:12	10:45	33	-1	2	16	2	0.13

Appendix 1. Continued

Site	Date	Dive Time			Depth (m)		Number of quadrats	Total number of abalone	Density (abalone/m^2)
		Start	Finish	Minutes	Min	Max			
Stryker Is									
ST121	Apr-25	13:58	15:02	64	0	4	16	15	0.94
ST190	Apr-25	13:08	13:27	19	0	3	8	0	0.00
ST220	Apr-25	11:12	11:34	22	0	1	8	0	0.00
ST304	Apr-25	9:34	10:26	52	-1	4	16	10	0.63
ST359	Apr-25	9:58	10:27	29	0	7	16	0	0.00
ST411	Apr-25	14:00	14:45	45	2	4	8	2	0.25
ST444	Apr-25	13:03	13:37	34	1	2	8	0	0.00
ST483	Apr-25	11:00	11:26	26	3	6	8	0	0.00
Simonds Group									
SI05	Apr-26	15:46	16:49	63	-2	2	16	23	1.44
SI09	Apr-26	11:03	11:45	42	2	6	16	8	0.50
SI16	Apr-26	11:31	11:54	23	1	7	16	1	0.06
SI20	Apr-26	10:27	11:06	39	2	6	16	2	0.13
SI21	Apr-26	9:50	10:10	20	0	2	8	0	0.00
SI30	Apr-26	10:05	10:27	22	1	2	8	0	0.00
Spider Is									
SP05	Apr-28	14:26	14:40	14	-2	3	8	0	0.00
SP08	Apr-28	14:10	14:35	25	1	2	16	2	0.13
SP13	Apr-28	13:12	14:00	48	0	2	16	11	0.69
SP17	Apr-28	10:48	11:11	23	2	7	16	10	0.63

Appendix 2. Site descriptions of the 55 index sites sampled along the central coast of BC, April 2001. The most common substrates are listed in order of dominance (1 = first, 2 = second, 3 = third) where substrate code 1 = smooth bedrock, 2 = bedrock with crevices, 3 = boulders, 4 = cobble, 5 = gravel, 6 = pea gravel, 7 = sand, 8 = shell. The algae are listed by growth characteristics for the most common (Sp 1) and second most common (Sp 2) with percentage cover (%) for each, where AC = articulated coralline algae, AG = *Agarum* sp., AL = *Alaria* Sp., BH = filamentous brown algae, CF = *Codium fragile*, CO = *Costaria costata*, CY = *Cymathere triplicate*, DE = *Desmarestia* sp., GH = filamentous green algae, LA = *Laminaria* sp., LE = *Leathesia difformis*, MA = *Macrocystis integrifolia*, NT = *Nereocystis luetkeana*, PH = *Phyllospadix* sp., PL = *Pleurophycus gardneri*, RF = foliose red algae, RH = filamentous red algae, UL = *Ulva* sp.

	Substrate			Slope	Canopy				Understory				Turf				Encrusting
Site	1	2	3	%	Sp	%	Sp	%	Sp	%	Sp	%	Sp	%	Sp	%	%
North Banks Is																	
44	3	4	7	2					CY	20	NT	15	UL	10	RH	1	75
45	3	4	7	8					NT	30	DE	20	UL	5	RF	1	75
46	3	2	8	11					LA	5	AL	5	AC	5			85
47	3			11													95
Oswald Bay																	
38	2			50	MA	10			AG	10	CY	10	AC	5			30
39	2	3	8	13									AC	2			90
40	3	5	6	4					LA	5			AC	5	UL	5	90
Pemberton Bay																	
33	3	4	8	8	MA	20			LA	20	DE	10	UL	1	RF	1	80
34	2	3	8	15	MA	35			LA	70	CY	5	AC	40			70
35	3	4	8	17					LA	25	PL	15	PH	5	AC	5	90
36	3	4	8	8					LA	20	NT	10	RH	2	AC	1	90
Lotbinière Bay																	
21	2	3	5	8					LA	70	AL	10	AC	5			90
22	3	4	5	8	MA	10	NT	2	PL	30	DE	25	AC	5			80
23	3	4	8	11					LA	90			AC	10	PH	10	95
24	3	7	5	11	MA	40			LA	15			AC	85	PH	10	70
25	2	3	4	23					NT	2	DE	1	UL	5	RH	1	95
27	3	4	5	4	NT	5			LA	70	PL	10	AC	5	RH	2	90
29	2	1		10	NT	5			LA	5			AC	25			45
30	3	4	7	8					LA	80	NT	10	AC	2	RH	1	90
North Aristazabal Is																	
13	2	5	8	11					LA	5			AC	10	LE	5	75
15	3	2	4	15					CY	2			AC	5	RH	2	60
15A	3	5	6	6									AC	2	GH	5	90
16	3	5	8	4	MA	50							AC	30			30
17	3	2	4	13					PL	25	DE	15	AC	1			80
19	3	2	4	8					LA	2	NT	2	GH	1	RH	1	80
20	2	3	4	10									AC	1			90

Appendix 2. Continued.

	Substrate			Slope	Canopy				Understory				Turf				Encrusting
Site	1	2	3	%	Sp	%	Sp	%	Sp	%	Sp	%	Sp	%	Sp	%	%
South Aristazabal Is																	
2	1	2		25					AL	25	LA	5	AL	2	GH	1	95
3	3	4	5	10					DE	5	CO	2	AC	10			100
4	3	4	5	11					DE	20							95
5	1	2		23					AL	2	NT	3					100
6	2			29					AL	60	LA	20	AC	60			90
7	1	2		10					DE	2	NT	2					100
8	2	1		25					DE	10			AC	20			70
9	3	4	5	2	MA	80							AC	30	RH	2	100
10	1	2		15					AL	35	NT	20	RH	5	AC	5	90
11	3	1	4	21					DE	5	CO	2	AC	2	CF	1	100
12	2	1		19					DE	2	NT	2	AC	2			100
Stryker Is																	
ST121	2	8		29					LA	60	AL	40	AC	10			90
ST190	2			46	NT	25			LA	75	AL	25	AC	40			100
ST220	1	3		15	NT	1			AL	60	LA	30	AC	10			100
ST304	1	2		25					LA	90	CO	20	AC	5	RH	2	100
ST359	2	8	4	48	MA	20			MA	30	AG	20	AC	5			90
ST411	1	2		30	NT	30			LA	100	NT	30	RH	20	RF	20	100
ST444	1	2		11	NT	50			LA	100	DE	50	RH	20			90
ST483	1	2		38					LA	90	NT	10	RH	20	BH	5	90
Simonds Group																	
SI05	3	2		17	NT	40			LA	80	CO	20	AC	10	RH	1	90
SI09	2	3	8	30					NT	2	CO	1	AC	5	RH	5	100
SI16	1	3	8	40					CY	80	NT	10	UL	5	RH	2	40
SI20	3	4	2	27	NT	50			NT	60	CO	40	RH	20			80
SI21	3	4		23	NT	5			CO	30	AL	25	BH	10	AC	5	50
SI30	3	2	4	27	NT	30			CO	60	AL	20	AC	10	RH	5	90
Spider Is																	
SP05	1	7		65	MA	90											5
SP08	3	4	7	10	NT	2			DE	50	NT	2					20
SP13	3			15	NT	5			AL	30			RH	5			80
SP17	2	3	4	32					AL	5	CO	5	AC	5			80

Appendix 3. Density of exposed abalone (number/m^2) by size category for index sites along the central coast, April 2001.

Site	Number of quadrats	Abalone counted	Total	Immature	Mature	Pre-recruit	New-recruit	Legal
North Banks Is								
44	16	7	0.44	0.13	0.31	0.00	0.06	0.19
45	16	1	0.06	0.00	0.06	0.00	0.00	0.06
46	16	10	0.63	0.19	0.44	0.06	0.06	0.19
47	16	10	0.63	0.19	0.44	0.13	0.06	0.06
Oswald Bay								
38	8	0	0.00	0.00	0.00	0.00	0.00	0.00
39	16	3	0.19	0.19	0.00	0.00	0.00	0.00
40	16	1	0.06	0.00	0.06	0.00	0.06	0.06
Pemberton Bay								
33	16	0	0.00	0.00	0.00	0.00	0.00	0.00
34	16	2	0.13	0.00	0.13	0.06	0.00	0.00
35	16	5	0.31	0.13	0.19	0.06	0.00	0.00
36	16	7	0.44	0.13	0.31	0.13	0.00	0.00
Lotbinière Bay								
21	16	6	0.38	0.00	0.38	0.06	0.19	0.25
22	16	7	0.44	0.06	0.38	0.00	0.06	0.13
23	16	11	0.69	0.00	0.69	0.06	0.06	0.13
24	8	0	0.00	0.00	0.00	0.00	0.00	0.00
25	16	1	0.06	0.06	0.00	0.00	0.00	0.00
27	16	0	0.00	0.00	0.00	0.00	0.00	0.00
29	16	18	1.13	0.56	0.56	0.06	0.00	0.06
30	16	10	0.63	0.19	0.44	0.06	0.13	0.13
North Aristazabal Is								
13	16	2	0.13	0.06	0.06	0.00	0.00	0.00
15	16	5	0.31	0.19	0.13	0.06	0.00	0.00
15A	16	4	0.25	0.13	0.13	0.00	0.00	0.00
16	16	15	0.94	0.38	0.56	0.25	0.00	0.06
17	16	7	0.44	0.25	0.19	0.06	0.00	0.00
19	16	0	0.00	0.00	0.00	0.00	0.00	0.00
20	16	1	0.06	0.06	0.00	0.00	0.00	0.00

Appendix 3. Continued.

Site	Number of quadrats	Abalone counted	Total	Immature	Mature	Pre-recruit	New-recruit	Legal
South Aristazabal Is								
2	16	1	0.06	0.06	0.00	0.00	0.00	0.00
3	16	1	0.06	0.06	0.00	0.00	0.00	0.00
4	16	1	0.06	0.00	0.06	0.00	0.00	0.00
5	8	0	0.00	0.00	0.00	0.00	0.00	0.00
6	16	2	0.13	0.06	0.06	0.00	0.00	0.00
7	16	2	0.13	0.13	0.00	0.00	0.00	0.00
8	16	1	0.06	0.06	0.00	0.00	0.00	0.00
9	16	3	0.19	0.06	0.13	0.00	0.00	0.00
10	8	0	0.00	0.00	0.00	0.00	0.00	0.00
11	16	2	0.13	0.06	0.06	0.00	0.00	0.00
12	16	2	0.13	0.13	0.00	0.00	0.00	0.00
Stryker Is								
ST121	16	15	0.94	0.13	0.81	0.13	0.06	0.19
ST190	8	0	0.00	0.00	0.00	0.00	0.00	0.00
ST220	8	0	0.00	0.00	0.00	0.00	0.00	0.00
ST304	16	10	0.63	0.44	0.19	0.06	0.00	0.00
ST359	16	0	0.00	0.00	0.00	0.00	0.00	0.00
ST411	8	2	0.25	0.13	0.00	0.00	0.00	0.00
ST444	8	0	0.00	0.00	0.00	0.00	0.00	0.00
ST483	8	0	0.00	0.00	0.00	0.00	0.00	0.00
Simonds Group								
SI05	16	23	1.44	0.25	1.19	0.25	0.38	0.50
SI09	16	8	0.50	0.25	0.25	0.06	0.00	0.00
SI16	16	1	0.06	0.00	0.06	0.00	0.06	0.06
SI20	16	2	0.13	0.00	0.13	0.06	0.00	0.00
SI21	8	0	0.00	0.00	0.00	0.00	0.00	0.00
SI30	8	0	0.00	0.00	0.00	0.00	0.00	0.00
Spider Is								
SP05	8	0	0.00	0.00	0.00	0.00	0.00	0.00
SP08	16	2	0.13	0.00	0.13	0.00	0.00	0.13
SP13	16	11	0.69	0.25	0.44	0.13	0.00	0.00
SP17	16	8	0.50	0.31	0.19	0.00	0.00	0.00

Appendix 4. 'All sizes' exposed abalone density (number/m^2) by index site and number of quadrats for all survey years. Blanks indicate site not surveyed.

	'All sizes' Density								Number of quadrats sampled per site							
Site	1979	1980	1983	1985	1989	1993	1997	2001	1979	1980	1983	1985	1989	1993	1997	2001
North Banks Is																
44	2.98					0.04	0.19	0.44	16					24	16	16
45	1.65					0.25	0.13	0.06	16					24	16	16
46	1.13					1.03	0.25	0.63	16					32	32	16
47	0.29					0.21	0.44	0.63	16					24	16	16
Oswald Bay																
38			2.26			0.59	0.56	0.00			16			32	16	8
39			4.13			0.38	0.44	0.19			16			32	16	16
40			0.59			0.47	0.00	0.06			16			32	8	16
Pemberton Bay																
33			1.68	0.84	0.50	1.25	0.31	0.00			16	15	16	32	16	16
34			2.28	0.98	0.00	0.00	0.00	0.13			16	17	8	8	16	16
35			3.09	1.35	0.06	0.41	0.44	0.31			16	16	16	32	16	16
36			1.51	3.32	1.44	0.17	0.81	0.44			16	16	16	24	16	16
Lotbinière Bay																
21	1.34		1.35	1.30	0.13	0.25	0.00	0.38	16		16	16	16	32	16	16
22	0.79		0.62	0.59	0.38	0.09	0.00	0.44	16		16	16	16	32	16	16
23	4.19		2.39	2.42	1.06	0.63	1.06	0.69	16		16	16	16	32	16	16
24	1.55		0.66	0.84	0.19	0.19	0.00	0.00	16		16	16	16	16	8	8
25			1.73	1.09	0.63	0.31	0.06	0.06			16	16	16	32	16	16
27		1.20	0.33	0.62	0.19	0.53	0.19	0.00		16	16	16	16	32	16	16
29			2.02	1.93	0.13	0.66	0.19	1.13			16	16	16	32	16	16
30			4.51	2.85	1.00	1.81	0.50	0.63			16	16	16	32	16	16

Appendix 4. Continued.

	Total Density								Number of quadrats sampled per site							
Site	1979	1980	1983	1985	1989	1993	1997	2001	1979	1980	1983	1985	1989	1993	1997	2001
North Aristazabal Is																
13			0.55	2.02	0.19	0.19	0.19	0.13			16	16	16	32	16	16
15			1.03	1.08	2.25	0.50	0.19	0.31			16	16	16	16	16	16
15A						0.44	0.13	0.25						16	16	16
16			0.34	1.22	0.25	0.88	0.63	0.94			16	16	16	32	16	16
17			1.60	2.16	0.94	0.44	0.19	0.44			16	16	16	32	16	16
18			0.00		1.13						8		16			
19			1.03	1.50	0.44	0.41	0.06	0.00			16	16	16	32	16	16
20			0.37	0.80	0.38	0.44	0.75	0.13			16	16	16	32	16	16
South Aristazabal Is																
2			0.23					0.06			16					16
3			0.68					0.06			16					16
4			0.50	0.23	1.31	0.13		0.06			16	16	16	24		16
5			0.00					0.00			8					8
6			0.92	0.23	0.06	0.33	0.13	0.13			16	16	16	24	16	16
7			2.09					0.13			8					16
8			2.27	2.71	0.50	0.28	0.00	0.06			16	16	16	32	8	16
9			0.86	1.01	0.19	0.04	0.06	0.19			16	16	16	24	16	16
10			0.97	4.06	0.50	0.28	0.13	0.00			16	16	16	32	16	8
11			0.72	1.66	0.38	0.63	0.25	0.13			16	16	16	16	16	16
12			0.68	1.00	0.00	0.88	0.25	0.13			16	16	8	16	16	16
Stryker Is																
ST121							2.56	0.94							16	16
ST190							0.63	0.00							16	8
ST220							0.69	0.00							16	8
ST304							0.31	0.63							16	16
ST359							0.19	0.00							16	16
ST411							0.19	0.25							16	8
ST444							0.50	0.00							16	8
ST483							0.44	0.00							16	8

Appendix 4. Continued.

Site	Total Density								Number of quadrats sampled per site							
	1979	1980	1983	1985	1989	1993	1997	2001	1979	1980	1983	1985	1989	1993	1997	2001
Simonds Group																
SI05							1.50	1.44							16	16
SI09							0.50	0.50							16	16
SI16							0.75	0.06							16	16
SI20							0.69	0.13							16	16
SI21							0.38	0.00							16	8
SI30								0.00								8
Spider Is																
SP05								0.00								8
SP08								0.13								16
SP13							0.19	0.69							16	16
SP17							1.56	0.63							16	16

Appendix 5. Legal and mature exposed abalone densities (number/m^2) by index site for all survey years. Blanks indicate site not surveyed.

	Legal density								Mature density							
Site	1979	1980	1983	1985	1989	1993	1997	2001	1979	1980	1983	1985	1989	1993	1997	2001
North Banks Is																
44	0.57						0.06	0.19	2.18						0.19	0.31
45	0.09					0.21	0.13	0.06	1.33					0.25	0.13	0.06
46	0.25					0.27	0.00	0.19	0.87					0.87	0.25	0.44
47	0.06					0.00	0.13	0.06	0.19					0.16	0.31	0.44
Oswald Bay																
38			0.32			0.22	0.25	0.00			2.10			0.53	0.56	0.00
39			1.10			0.00	0.06	0.00			3.66			0.19	0.38	0.00
40			0.12			0.03	0.00	0.06			0.43			0.38	0.00	0.06
Pemberton Bay																
33			0.19	0.07	0.00	0.03	0.00	0.00			1.41	0.73	0.38	0.94	0.06	0.00
34			0.29	0.17	0.00	0.00	0.00	0.00			1.90	0.93	0.00	0.00	0.00	0.13
35			0.19	0.06	0.00	0.00	0.19	0.00			2.04	0.31	0.00	0.13	0.44	0.19
36			0.13	0.99	0.13	0.04	0.06	0.00			0.97	3.16	1.06	0.08	0.69	0.31
Lotbinière Bay																
21	0.83		0.42	0.93	0.13	0.22	0.00	0.25	1.19		0.95	1.30	0.13	0.25	0.00	0.38
22	0.29		0.31	0.19	0.31	0.06	0.00	0.13	0.69		0.62	0.43	0.38	0.06	0.00	0.38
23	0.87		0.25	0.12	0.19	0.03	0.19	0.13	3.29		1.55	2.11	0.97	0.41	0.88	0.69
24	0.38		0.00	0.31	0.06	0.13	0.00	0.00	1.24		0.56	0.68	0.19	0.19	0.00	0.00
25			0.37	0.29	0.25	0.03	0.00	0.00			1.67	0.94	0.56	0.25	0.06	0.00
27		0.27	0.12	0.25	0.19	0.16	0.19	0.00		0.68	0.12	0.62	0.19	0.41	0.19	0.00
29			0.29	0.70	0.00	0.00	0.06	0.06			1.87	1.66	0.13	0.31	0.19	0.56
30			0.89	1.43	0.30	0.25	0.25	0.13			3.75	2.85	1.00	1.59	0.50	0.44

Appendix 5. Continued.

Site	Legal density								Mature density							
	1979	1980	1983	1985	1989	1993	1997	2001	1979	1980	1983	1985	1989	1993	1997	2001
North Aristazabal Is																
13			0.06	0.26	0.00	0.00	0.13	0.00			0.50	1.21	0.19	0.06	0.19	0.06
15			0.25	0.12	0.12	0.00	0.00	0.00			0.93	0.56	1.72	0.13	0.06	0.13
15A						0.06	0.00	0.00						0.38	0.00	0.13
16			0.06	0.13	0.06	0.06	0.00	0.06			0.19	0.78	0.25	0.53	0.06	0.56
17			0.00	0.00	0.06	0.03	0.00	0.00			0.87	1.43	0.63	0.13	0.13	0.19
18			0.00		0.00						0.00		0.50			
19			0.53	0.56	0.19	0.15	0.06	0.00			0.90	1.24	0.31	0.30	0.06	0.00
20			0.31	0.37	0.19	0.38	0.38	0.00			0.37	0.74	0.38	0.41	0.75	0.00
South Aristazabal Is																
2			0.00					0.00			0.17					0.00
3			0.00					0.00			0.00					0.00
4			0.25	0.06	0.07	0.00		0.00			0.50	0.12	0.39	0.00		0.06
5			0.00					0.00			0.00					0.00
6			0.00	0.00	0.00	0.04	0.00	0.00			0.19	0.12	0.00	0.13	0.00	0.06
7			0.00					0.00			0.00					0.00
8			0.38	0.25	0.19	0.00	0.00	0.00			2.17	2.29	0.31	0.00	0.00	0.00
9			0.00	0.43	0.00	0.00	0.00	0.00			0.81	0.81	0.06	0.04	0.06	0.13
10			0.19	1.04	0.14	0.13	0.00	0.00			0.87	3.91	0.50	0.28	0.00	0.00
11			0.07	0.00	0.13	0.00	0.00	0.00			0.27	0.62	0.38	0.25	0.06	0.06
12			0.25	0.19	0.00	0.13	0.00	0.00			0.68	0.74	0.00	0.50	0.25	0.00
Stryker Is																
ST121							0.50	0.19							2.13	0.81
ST190							0.00	0.00							0.50	0.00
ST220							0.31	0.00							0.69	0.00
ST304							0.00	0.00							0.19	0.19
ST359							0.00	0.00							0.13	0.00
ST411							0.00	0.00							0.00	0.00
ST444							0.00	0.00							0.06	0.00
ST483							0.00	0.00							0.00	0.00

Appendix 5. Continued.

Site	Legal density								Mature density							
	1979	1980	1983	1985	1989	1993	1997	2001	1979	1980	1983	1985	1989	1993	1997	2001
Simonds Group																
SI05							0.75	0.50							1.25	1.19
SI09							0.00	0.00							0.44	0.25
SI16							0.50	0.06							0.75	0.06
SI20							0.31	0.00							0.56	0.13
SI21							0.00	0.00							0.06	0.00
SI30								0.00								0.00
Spider Is																
SP05								0.00								0.00
SP08								0.13								0.13
SP13							0.19	0.00							0.19	0.44
SP17							0.00	0.00							0.50	0.23

Appendix 6. Pre-recruit and new-recruit exposed abalone densities (number/m^2) by index site for all survey years. Blanks indicate site not surveyed.

	Pre-recruit density								New-recruit density							
Site	1979	1980	1983	1985	1989	1993	1997	2001	1979	1980	1983	1985	1989	1993	1997	2001
North Banks Is																
44	0.47						0.00	0.00	0.19						0.00	0.06
45	0.28					0.04	0.00	0.00	0.09					0.13	0.06	0.00
46	0.25					0.16	0.03	0.06	0.19					0.13	0.00	0.06
47	0.03					0.05	0.00	0.13	0.02					0.00	0.13	0.06
Oswald Bay																
38			0.76			0.13	0.19	0.00			0.13			0.09	0.13	0.00
39			0.79			0.06	0.13	0.00			0.31			0.00	0.00	0.00
40			0.19			0.03	0.00	0.00			0.00			0.03	0.00	0.06
Pemberton Bay																
33			0.19	0.13	0.13	0.25	0.00	0.00			0.06	0.07	0.00	0.00	0.00	0.00
34			0.34	0.12	0.00	0.00	0.00	0.06			0.11	0.12	0.00	0.00	0.00	0.00
35			0.25	0.06	0.00	0.03	0.13	0.06			0.19	0.06	0.00	0.00	0.06	0.00
36			0.06	0.62	0.31	0.00	0.19	0.13			0.06	0.62	0.13	0.04	0.00	0.00
Lotbinière Bay																
21	0.00		0.06	0.19	0.00	0.00	0.00	0.06	0.00		0.24	0.50	0.06	0.06	0.00	0.19
22	0.06		0.12	0.06	0.00	0.00	0.00	0.00	0.12		0.06	0.12	0.00	0.03	0.00	0.06
23	0.58		0.12	0.43	0.14	0.06	0.00	0.06	0.29		0.12	0.06	0.10	0.00	0.13	0.06
24	0.11		0.00	0.06	0.06	0.06	0.00	0.00	0.16		0.00	0.19	0.06	0.00	0.00	0.00
25			0.37	0.23	0.13	0.13	0.00	0.00			0.31	0.12	0.13	0.00	0.00	0.00
27		0.07	0.00	0.19	0.00	0.13	0.00	0.00		0.21	0.06	0.19	0.06	0.03	0.00	0.00
29			0.23	0.51	0.00	0.06	0.06	0.06			0.29	0.45	0.00	0.00	0.06	0.00
30			1.19	0.56	0.30	0.25	0.13	0.06			0.77	0.74	0.10	0.19	0.00	0.13

Appendix 6. Continued.

Site	Pre-recruit density								New-recruit density							
	1979	1980	1983	1985	1989	1993	1997	2001	1979	1980	1983	1985	1989	1993	1997	2001
North Aristazabal Is																
13			0.00	0.13	0.00	0.00	0.06	0.00			0.00	0.13	0.00	0.00	0.00	0.00
15			0.37	0.06	0.47	0.00	0.06	0.06			0.12	0.06	0.06	0.00	0.00	0.00
15A						0.00	0.00	0.00						0.00	0.00	0.00
16			0.00	0.07	0.06	0.13	0.06	0.25			0.06	0.07	0.00	0.06	0.00	0.00
17			0.06	0.25	0.13	0.03	0.06	0.06			0.00	0.00	0.06	0.03	0.00	0.00
18			0.00		0.00						0.00		0.00			
19			0.23	0.37	0.00	0.10	0.00	0.00			0.30	0.25	0.06	0.10	0.06	0.00
20			0.00	0.25	0.13	0.03	0.06	0.00			0.00	0.06	0.06	0.22	0.06	0.00
South Aristazabal Is																
2			0.00					0.00			0.00					0.00
3			0.00					0.00			0.00					0.00
4			0.12	0.06	0.07	0.00		0.00			0.12	0.06	0.00	0.00		0.00
5			0.00					0.00			0.00					0.00
6			0.00	0.00	0.00	0.04	0.00	0.00			0.00	0.00	0.00	0.04	0.00	0.00
7			0.00					0.00			0.00					0.00
8			0.45	0.50	0.00	0.00	0.00	0.00			0.19	0.00	0.06	0.00	0.00	0.00
9			0.19	0.06	0.00	0.00	0.00	0.00			0.00	0.25	0.00	0.00	0.00	0.00
10			0.06	1.10	0.00	0.13	0.00	0.00			0.06	0.73	0.07	0.09	0.00	0.00
11			0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.06	0.00	0.00	0.00
12			0.06	0.19	0.00	0.13	0.06	0.00			0.12	0.06	0.00	0.00	0.00	0.00
Stryker Is																
ST121							0.44	0.13							0.31	0.06
ST190							0.06	0.00							0.00	0.00
ST220							0.13	0.00							0.25	0.00
ST304							0.00	0.06							0.00	0.00
ST359							0.00	0.00							0.00	0.00
ST411							0.00	0.00							0.00	0.00
ST444							0.00	0.00							0.00	0.00
ST483							0.00	0.00							0.00	0.00

Appendix 6. Continued.

Site	Pre-recruit density								New-recruit density							
	1979	1980	1983	1985	1989	1993	1997	2001	1979	1980	1983	1985	1989	1993	1997	2001
Simonds Group																
SI05							0.31	0.25							0.31	0.38
SI09							0.00	0.06							0.00	0.00
SI16							0.13	0.00							0.13	0.06
SI20							0.13	0.06							0.13	0.00
SI21							0.00	0.00							0.00	0.00
SI30								0.00								0.00
Spider Is																
SP05								0.00								0.00
SP08								0.00								0.00
SP13							0.00	0.13							0.13	0.00
SP17							0.19	0.00							0.00	0.00

Appendix 7. Exposed abalone densities (number/m^2) across all size categories for additional (non-repeated) surveyed sites during the 1978, 1979, 1980, 1983, and 1985 central coast surveys.

Year-Site	Number of quadrats	Total	Immature	Mature	Pre-recruit	New Recruit	Legal
78-01	16	4.88	0.19	4.69	0.31	0.38	3.00
78-02	16	0.63	0.25	0.38	0.00	0.00	0.38
78-03	12	0.58	0.00	0.58	0.00	0.17	0.50
78-05	16	2.69	0.24	2.44	0.49	0.37	0.79
78-06	14	5.07	0.85	4.23	0.85	0.61	1.77
78-07	16	3.19	0.84	2.35	0.54	0.12	0.30
78-08	16	2.31	0.00	2.31	0.31	0.31	1.69
78-09	16	2.81	0.17	2.64	0.75	0.63	1.32
78-10	16	2.25	0.33	1.92	0.26	0.07	0.93
78-11	16	1.50	0.06	1.44	0.13	0.38	0.88
78-12	16	0.88	0.00	0.88	0.10	0.10	0.51
78-13	16	2.06	0.35	1.71	0.12	0.41	1.18
79-14	14	1.02	0.18	0.84	0.18	0.16	0.26
79-22	16	4.75	0.77	3.98	0.98	0.91	1.17
79-23	16	3.62	1.17	2.46	0.19	0.04	0.15
79-24	16	5.50	1.72	3.78	0.99	0.74	0.99
79-27	16	2.83	1.10	1.73	0.43	0.31	0.37
80-03	16	3.80	2.56	1.24	0.13	0.06	0.06
80-10	16	5.09	0.27	4.83	1.40	0.13	0.63
80-12	16	0.68	0.25	0.43	0.06	0.13	0.12
80-18	13	5.77	2.57	3.20	0.46	0.31	0.38
80-22	16	7.57	3.91	3.66	0.24	0.12	0.18
80-29	16	2.63	1.49	1.14	0.00	0.00	0.00
80-30	16	1.71	0.11	1.61	0.32	0.58	0.64
80-52	16	3.98	0.26	3.72	0.67	0.67	1.65
80-53	14	3.38	1.65	1.73	0.38	0.08	0.15
80-57	16	1.95	0.86	1.09	0.00	0.13	0.19
80-58	16	6.72	4.82	1.91	0.00	0.00	0.00
80-59	16	4.14	2.04	2.10	0.32	0.25	0.25
80-61	16	1.41	1.07	0.34	0.00	0.00	0.00
80-62	18	1.75	0.96	0.79	0.34	0.11	0.11
80-63	16	0.60	0.09	0.51	0.06	0.17	0.23
80-65	16	1.41	0.42	0.99	0.00	0.06	0.06
80-66	16	0.46	0.18	0.28	0.00	0.00	0.00
80-68	12	4.38	2.64	1.74	0.09	0.09	0.09
83-14	16	1.98	0.37	1.61	0.12	0.12	0.12
83-26	16	9.97	2.67	7.31	1.48	0.56	0.91
83-28	16	1.47	0.11	1.35	0.47	0.41	0.61

Appendix 7. Continued.

Year-Site	Number of quadrats	Total	Immature	Mature	Pre-recruit	New Recruit	Legal
83-31	16	1.14	0.21	0.93	0.25	0.25	0.31
83-32	16	3.75	0.51	3.23	0.85	0.24	0.49
83-37	16	2.36	0.31	2.04	0.37	0.12	0.19
83-41	16	0.90	0.16	0.74	0.06	0.00	0.00
83-42	16	0.36	0.05	0.31	0.12	0.06	0.06
83-43	16	0.50	0.00	0.50	0.21	0.14	0.14
85-01	16	2.55	1.26	1.29	0.27	0.07	0.07
85-02	16	0.72	0.14	0.57	0.06	0.11	0.11
85-18b	16	0.90	0.15	0.76	0.35	0.06	0.06